CHAPTER 9

OPERATIONAL OCEANOGRAPHY

In this chapter we will be discussing information on a number of oceanography products and environmental factors of utmost importance to the Aerographer's Mate.

By being familiar with these products, parameters, limitations, and request procedures the Aerographer can provide the on-scene commander with a detailed accounting of environmental conditions above, as well as below, the ocean's surface.

We will first discuss the products available from the Navy Oceanographic Data Distribution System (NODDS). NODDS was developed in 1982 as a means to make FLENUMETOCCEN (FNMOC) environmental products available to METOCFACS and METOCDETS who had no direct access to this data. Through the years, the system has grown in use as product support has expanded. NODDS 3.0 was distributed in December 1991, and it was unique in its approach to environmental data communications. Once a user has defined the products desired for a specific area, an automatic process of acquiring data is initiated. Using a commercial "off the shelf" licensed communications software package, the system dials FLENUMMETOCCEN and requests the data fields from a security shell in a host mainframe computer. The required data is extracted from one of the global data bases as a compacted ASCII transmission which is generated for each field/product. By transmitting field data and limiting the area of extraction, the transmissions are small and communications are efficient. Once the raw data is received by the user's NODDS, the required contouring, streamlining, shading, and so forth, is performed automatically until all products are in a ready-to-display format.

The NODDS User's Manual contains explanations of system functions and step-by-step procedures for using the NODDS terminal, By selecting the "Convert Data" option of the "Data Manager" file from the main menu the user can convert the NODDS geographic displays to alphanumeric displays. Underway units may also access NODDS data using a VHF Stel Modem along with a STU-III Secure phone. There are limitations associated with all of the NODDS acoustic products listed in this section, such as low grid resolutions and graphic depiction errors. A general description of each product will be covered along with example outputs. Further discussion on parameter derivation and user provided inputs may be found in the NODDS Products Manual, FLENUMMETOCCENINST 3147.1. Now let's look at some of the products available from NODDS.

CONVERGENCE ZONE RANGE (CZR)

LEARNING OBJECTIVES Recognize characteristics of a convergence zone. Evaluate CZR products. Identify the two graphic outputs of the product.

The CZR product predicts the expected ranges to the first convergence zone for a sonar. Convergence zones are regions in the deep ocean where sound rays, refracted from the depths, are focused at or near the surface. Convergence zones are repeated at regular range intervals and have been observed out to 500 nmi or more. Convergence zone ranges are those ranges capable of being achieved when operating sonar in the path of a convergence zone.

SOUND DISTRIBUTION

The distribution of sound throughout the deep ocean is characterized by a complex series of shadow zones and convergence zones. The presence and extent of these zones are determined by the sound speed profile, the location of the surface, bottom, and source relative to the profile, and the existence of caustics.

CAUSTICS

A caustic is the envelope formed by the intersection of adjacent rays. When a caustic intersects the sea surface or a region at or near the surface, a convergence zone is created. Convergence zones are regions of high sound intensity. Thus, a receiver may be expected to pick up high sound intensity gain within a convergence zone versus outside of it, where only a single strong propagation path occurs.

CONVERGENCE ZONE REQUIREMENTS

The existence of a convergence zone requires a negative sound-speed gradient at or near the surface and a positive gradient below. In addition, there must be sufficient depth for usable convergence zone to occur, that is, the water column must be deeper than the limiting depth by at least 200 fathoms.

SOUND SPEED PROFILE

The sound speed profile of the deep ocean varies with latitude. In cold surface waters the depth of the deep sound channel axis is shallow, the range to the convergence zone is small, and the range interval between zones is small. In the Mediterranean Sea, the bottom water is much warmer than in the open ocean and, consequently, the sound speed near the bottom is higher. Since the limiting depth is much shallower and the acoustic energy is refracted upward at a much shallower depth, ranges are much shorter than those generally found in the open ocean.

Although the acoustic characteristics and sufficient depth excess for convergence zone propagation may exist, bathymetry does play a role as the presence of a seamount or ridge may block the convergence zone path.

EXAMPLE OUTPUT

There are two graphic outputs available with the CZR product.

1. A shaded convergence zone range display, which depicts areas of predicted range in nautical miles (nmi). See figure 9-1. The amount of the shading indicates the range as follows:

Clear	No CZs
Light	Short range CZs
Medium	Medium range CZs
Heavy	Long range CZs

2. The shaded convergence zone usage product displays the areas of CZ probability based on an analysis of depth and/or sound speed excess. See figure 9-2. The amount of shading indicates the probability as follows:

Clear	No CZs
Medium	Possible CZs
Heavy	Reliable CZs

BOTTOM BOUNCE RANGE (BBR)

LEARNING OBJECTIVES: Explain the theory associated with the BBR. Evaluate BBR products. Identify the two graphic outputs of the product.

The BBR product provides an estimate of the horizontal ranges expected for active sonars operating in the bottom bounce mode.

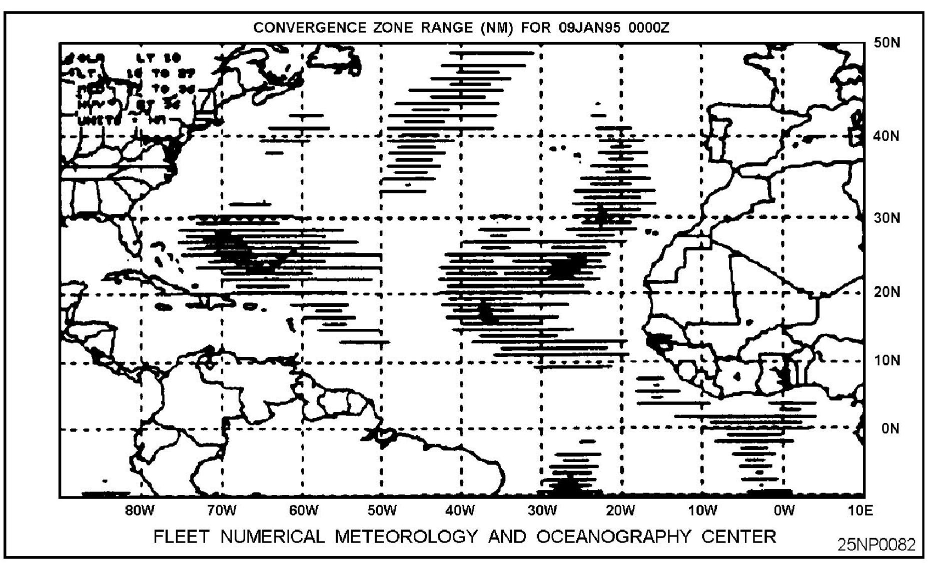

Figure 9-1.-A shaded convergence zone range display.

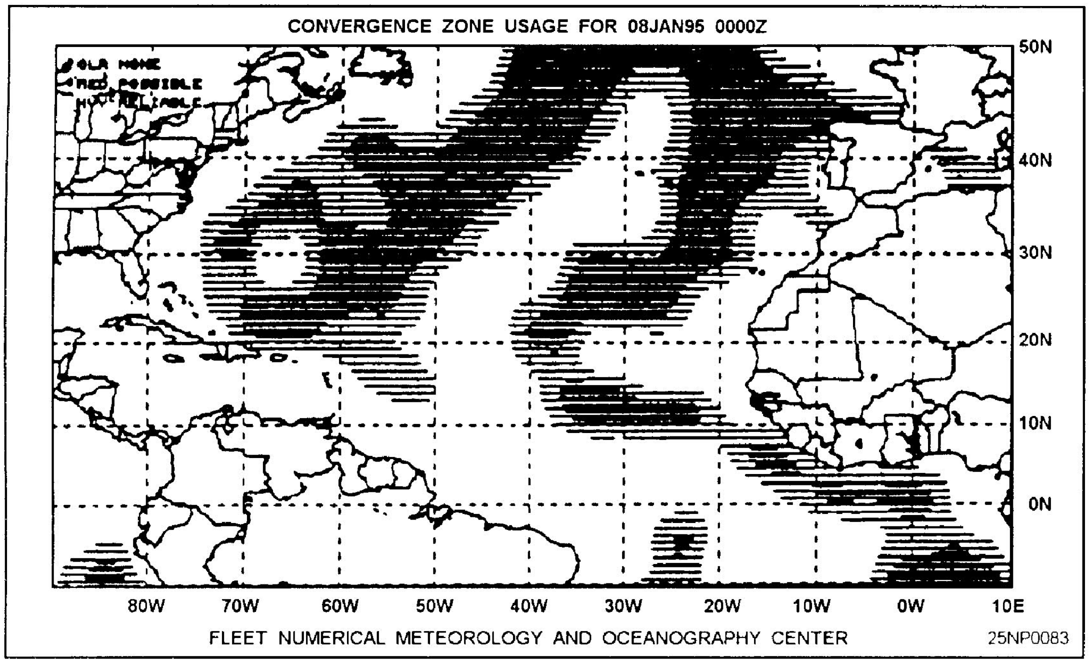

Figure 9-2.-A shaded contoured convergence zone probability display.

In the bottom bounce mode, sound energy is directed towards the bottom. This path is successful because the angle of the sound ray path is such that the sound energy is affected to a lesser degree by sound speed changes than the more nearly horizontal ray paths of other transmission modes (that is, surface duct, deep sound channel, convergence zone).

RANGE VERSUS DEPTH

Long-range paths can occur with water depths greater than 1,000 fathoms, depending on bottom slope. At shallower depths high intensity loss is produced from multiple-reflected bottom bounce paths that develop between the source and receiver. Since 85 percent of the ocean is deeper than 1,000 fathoms and bottom slopes are generally less than or equal to 1°, relatively steep angles can be used for single bottom reflection. With steeply inclined rays, transmission is relatively free from thermal effects at the surface, and the major part of the sound path is in nearly stable water.

ACTIVE DETECTION

Inactive detection, bottom bounce transmission can produce extended ranges with fewer shadow zones because more than one single-reflected bottom path exists between the sonar and the target. These paths combine to produce an increase in the received signal and reduce the extent of the shadow zone. The major factors affecting bottom bounce transmission include the angle at which the sound ray strikes the bottom (grazing angle), the sound frequency, the bottom composition, and the bottom roughness.

EXAMPLE OUTPUT

There are two graphic outputs available with the BBR product.

1. A shaded bottom bounce range display. The amount of shading indicates the range in nmi. See figure 9-3.

Light	1-5 nmi range
Medium	5-10 nmi range
Heavy	>10 nmi range

2. A shaded bottom bounce probability display. This product provides estimates of the existence of low-loss bottom bounce paths between a sonar (source) and the target (receiver) based on the environmental and geoacoustic parameters. See figure 9-4. The amount of shading indicates the probability conditions as follows:

Clear	No
Medium	Fair
Heavy	Good

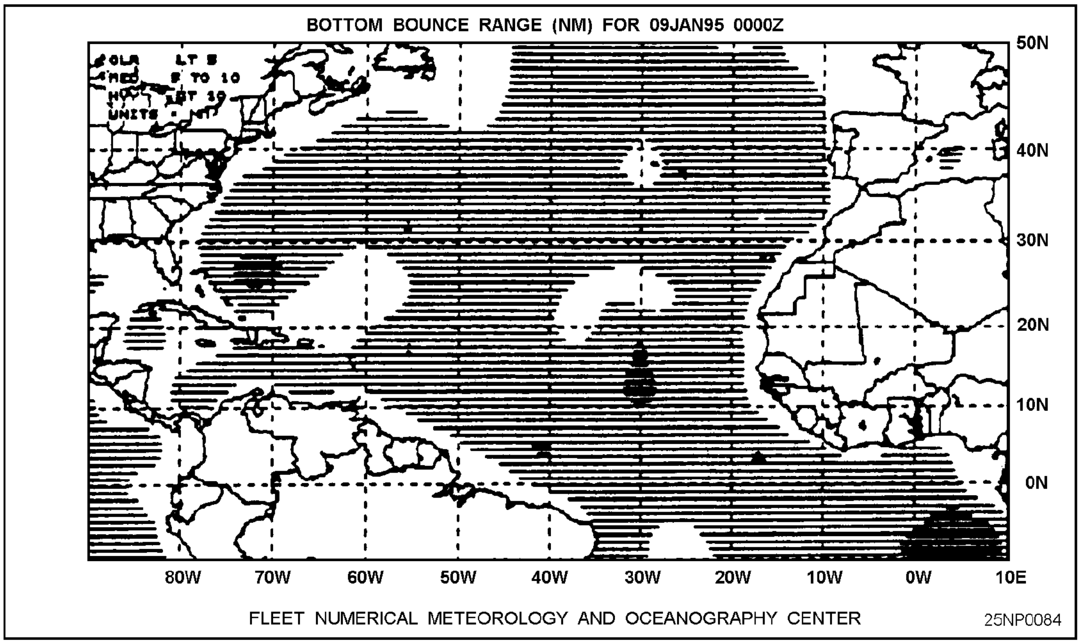

Figure 9-3.-A shaded bottom bounce range display.

SONIC LAYER DEPTH (SLD)

LEARNING OBJECTIVES Recognize characteristics of the SLD. Evaluate SLD product. Identify the graphic output products.

The SLD product displays the layer depth that can be used to locate areas of strong sound propagation in the near-surface layer. The sound field in a layer depends greatly upon the layer depth. The deeper the layer, the farther the sound can travel without having to reflect off the surface and the greater is the amount of energy initially trapped.

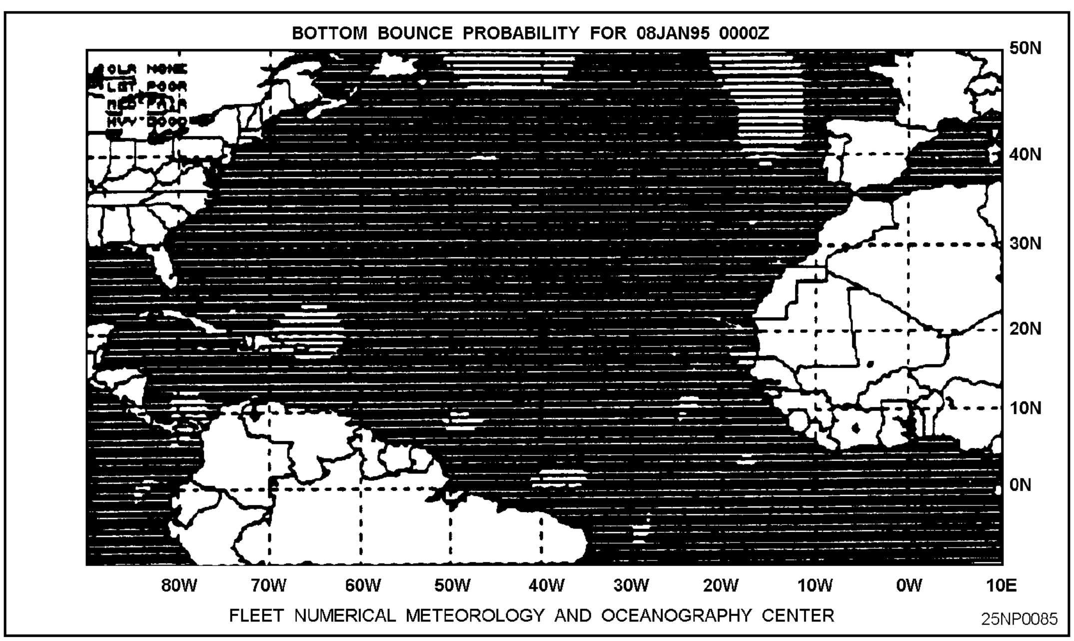

Figure 9-4.-A shaded bottom bounce probability display.

EXAMPLE OUTPUT

There is only one graphic output available with the SLD product. It is a shaded sonic layer depth display. The amount of shading indicates the range of depth in feet. See figure 9-5.

Clear	<50 ft
Light	50-100 ft
Medium	100– 350 ft
Heavy	>350 ft

SURFACE DUCT CUTOFF FREQUENCY (SFD)

LEARNING OBJECTIVES: Describe the two conditions under which a surface duct may occur. Evaluate the SFD product. Identify the graphic output of the product.

The SFD product displays the cutoff frequency values where a surface duct may occur in the mixed layer of the ocean if one of two conditions exist: (1) the temperature in the layer increases with depth or (2) an isothermal layer is near the surface. In condition 1, sound speed increases as the temperature increases. In condition 2, there is no temperature or salinity gradient and pressure causes sound speed to increase with depth.

In the mixed (or surface) layer the velocity of sound is susceptible to the daily and local changes of heating, cooling, and wind action. Under prolonged calm and sunny conditions the mixed layer disappears and is replaced by water where the temperature decreases with depth.

ADVANTAGES OF THE SURFACE DUCT

The potential for using these ducts in long-range detection was not fully realized in early sonar operation since the equipment was generally in the supersonic frequency range (24 kHz and above) and attenuation due to leakage and absorption was great. As a result of the continuous trend in sonar toward lower frequencies, the use of this duct is an aid for both active and passive detection.

FREQUENCY

At low frequencies, sound will not be trapped in the surface duct. This occurs when the frequency approaches the cutoff frequency; that is, the wavelength has become too large to “fit” in the duct. This does not represent a sharp cutoff. However, at frequencies much lower than the cutoff frequency, sound energy is strongly attenuated by scattering and leakage out of the duct.

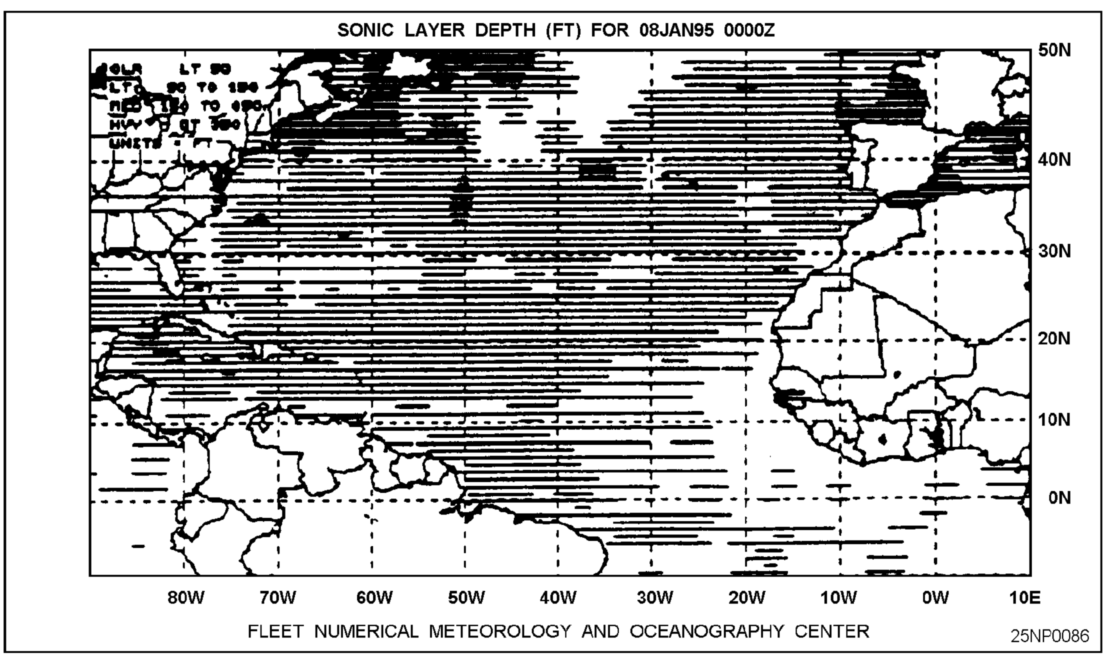

Figure 9-5.-A shaded sonic layer depth display.

DUCT QUALITY

The quality of transmission in the surface duct varies greatly with the thickness of the duct, surface roughness, gradient below the layer, and frequency.

EXAMPLE OUTPUT

There is one graphic output available with the SFD product. It is a shaded surface duct cutoff frequency display. The amount of shading indicates the range of frequencies. See figure 9-6.

Clear	No duct or >300 Hz
Light	150-300 Hz
Medium	50-150 Hz
Heavy	1 -5 0 Hz

DIRECT PATH RANGE (DPR)

LEARNING OBJECTIVES: Understand the conditions under which DPRs are most likely to occur. Evaluate the DPR product. Identify the graphic output of the program.

The DPR displays the most probable ranges that can be expected for acoustic surveillance system modes that use direct path propagation. The direct path is the simplest propagation path. It occurs where there is approximately a straight-line path between sonar (source) and target (receiver), with no reflection and only one change of direction due to refraction. The maximum range obtained in the direct path propagation mode occurs out to the point at which the surface duct limiting ray comes back up and is reflected from the surface.

EXAMPLE OUTPUT

There is one graphic output available with the DPR product, a shaded direct path range display. The amount of shading indicates the range in nmi. See figure 9-7.

Light	0-2 nmi
Medium	2-4 nmi
Heavy	>4 nmi

HALF-CHANNEL CONDITIONS (HAF)

LEARNING OBJECTIVES: Understand the situations that are most favorable for HAF. Evaluate the HAF product. Identify the graphic output of the program.

The HAF product displays areas where positive sound speed profile gradient (half-channel) conditions

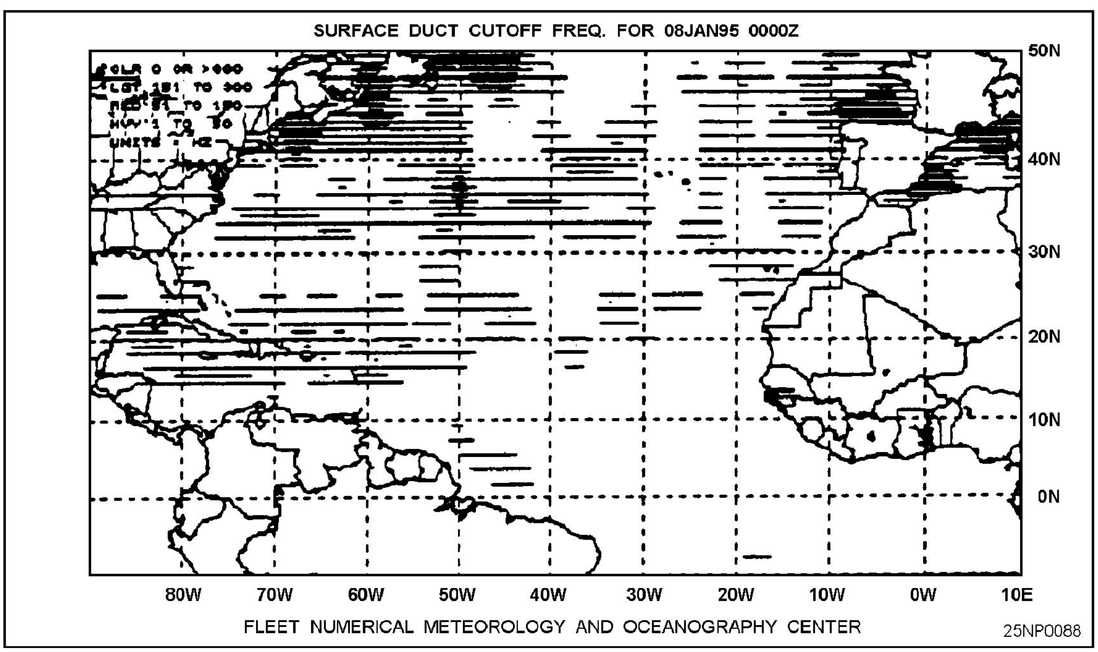

Figure 9-6.-A shaded surface duct cutoff frequency display.

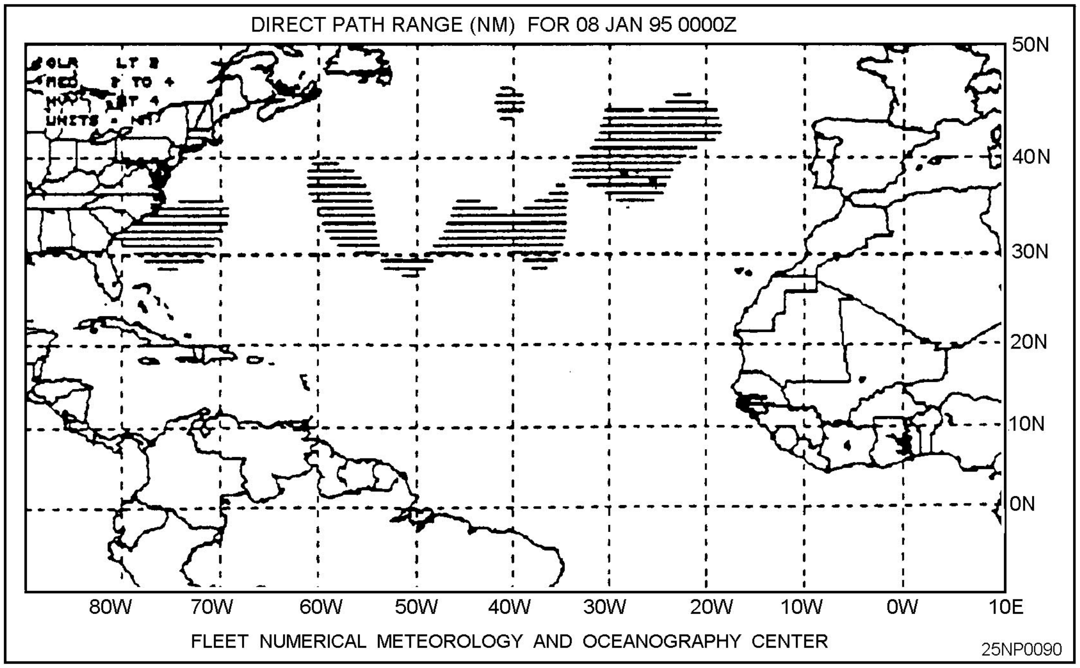

Figure 9-7.-A shaded direct path range display.

exist. Half-channel conditions exist where the water is essentially isothermal from the sea surface to the bottom, so that sound speed increases continuously with increasing depth. Under these conditions, the greatest sound speed is at the bottom of the ocean, and sound energy will be refracted upward, then reflected downward at the surface, and refracted upward again. The effect is similar to a strong surface duct, so long ranges are possible. Half-channel propagation is common during winter in the Mediterranean Sea and polar regions.

EXAMPLE OUTPUT

There is one graphic output available with the HAF product. It is a shaded half-channel conditions display. The half-channel conditions are indicated by the vertical shading: clear no; heavy yes. See figure 9-8.

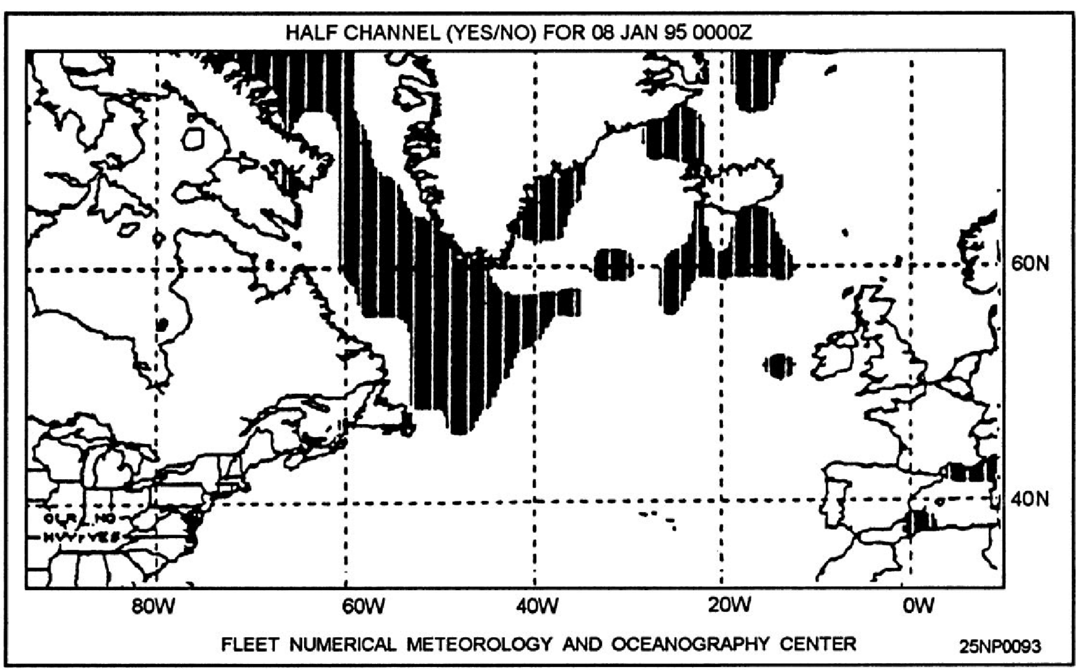

Figure 9-8.-A shaded half-channel conditions display.

SOUND CHANNEL AXIS DEPTH

LEARNING OBJECTIVES: Recognize subsurface oceanographic features conducive to deep and shallow channel conditions. Evaluate deep sound channel axis (DSC) and shallow sound channel axis (SSX) depth products. Identify the graphic and tabular outputs of each.

In this section we will discuss both the deep and shallow channel axis products. First, let's look at the deep sound channel axis.

DEEP SOUND CHANNEL AXIS DEPTH (DSC)

A deep sound channel occurs when the deep sea is warm on top and cold below. The surface-warming effect is not sufficient to extend all the way to the bottom and is limited to the upper part of the water column, below which it forms the main thermocline. The main thermocline exhibits a decrease in temperature at a moderately rapid rate with depth. Below the main thermocline, the sea is nearly isothermal about 38°F) and therefore has a positive sound speed gradient due to the effects of pressure.

Sound Ray Refraction

The DSC axis is located at the depth of minimum sound speed in the deep sound channel. This sound speed minimum causes the sea to act like a kind of lens, as expressed by Snell's law, where sound rays above and below the minimum are continuously bent by refraction toward the DSC axis. That is, as the ray enters the deep sound channel from above, the sound speed follows a negative gradient and the ray bends downward toward the depth of the minimum sound speed, the axis. Conversely, after the ray reaches the axis, the sound speed gradient is positive and the ray bends upward toward the axis.

This refraction pattern forms the low-loss deep sound channel, as a portion of the power radiated by a source in the deep sound channel remains within the channel and encounters no acoustic losses by reflection from the sea surface and bottom. Because of the low transmission loss, very long ranges can be obtained from a source of moderate acoustic power output, especially when it is located near the depth of minimum velocity, the axis of the sound channel. Note that not all propagation paths in the DSC are entirely refracted paths. When the source or receiver or both lie beyond the limits of the channel, only reflected paths that encounter either the surface or bottom or both are possible.

Ocean Variations

The ocean by no means is laterally uniform. Because the temperature structure of the ocean varies with location, the axis depth ranges from 4,000 feet (1,225 meters) in mid-latitudes to near-surface in polar regions. As the channel axis becomes shallower, low values of attenuation can be reported. For example, the channel axis becomes shallower with increasing latitude northward from Hawaii, so a shallow source finds itself closer to the DSC axis as it moves northward. As a result, the transmission becomes better than it would be if the DSC axis were at a constant depth. Also, signals in the DSC can be found to reach a maximum and then begin to decrease with increasing range instead of the normal linear decrease. This effect is attributed to poor sound channel conditions along part of the path. The horizontal variations of the DSC axis can be readily observed on the DSC product.

Sound Fixing and Ranging (SOFAR) Channel

The deep sound channel is sometimes referred to as the SOFAR (sound fixing and ranging) channel. Its remarkable transmission characteristics were used in the SOFAR system for rescue of aviators downed at sea. In SOFAR a small explosive charge is dropped at sea by a downed aviator and is received at shore stations thousands of miles away. The time of arrival at two or more stations gives a "fix," locating the point at which the detonation of the charge took place. More recently, the ability to measure accurately the arrival time of explosive signals traveling along the axis of the deep sound charnel has been used for geodetic distance determinations and missile-impact locations as a part of the Missile Impact Location System (MILS) network.

EXAMPLE OUTPUT

There is one graphic output available with the DSC product. It is a shaded deep sound channel axis depth display. The amount of shading indicates the range of depth in feet. See figure 9-9.

Clear	< 1,500 feet
Light	1,500 – 3,000 feet
Medium	3,000-4,500 feet
Heavy	>4,500 feet

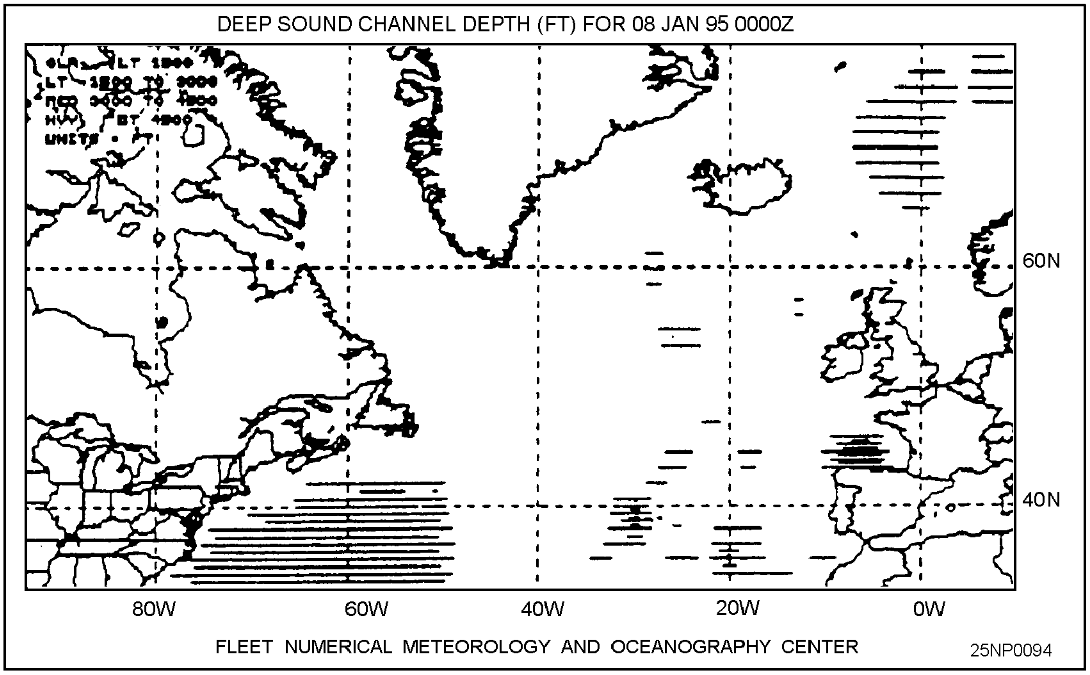

Figure 9-9.-A shaded deep sound channel axis depth display.

SHALLOW SOUND CHANNEL AXIS DEPTH (SSX)

The SSX product displays the axis depth values used in determining whether useful shallow sound channels (or ducts) exist within the area specified.

Thermocline and Mixed Layer Relationships

Shallow subsurface sound channels occur in the upper levels of the water column in the thermocline. The thermocline is the layer of sea water where the temperature decreases continuously with depth between the isothermal mixed layer and the deep sound channel axis. The relative strength of a sound channel depends upon the thickness of the channel and the maximum angle of the trapped rays.

Geographic Locations

Studies indicate that shallow sound channels beneath the mixed layer depth occur most often north of 40°N in the area between Hawaii and the continental United States. They are also frequently observed in the vicinity of the Gulf Stream. The prevalent depth of these shallow channels ranges from 90 to 150 meters.

During the summer a shallow channel exists in the Mediterranean Sea. In this region, the heating by the sun of the upper layers of the water, together with an absence of mixing by the wind, causes a strong near-surface negative gradient to develop during the spring and summer months. This thermocline overlies isothermal water at greater depths. The result is a strong sound channel with its axial depth near 100 meters. Although shallow sound channels are more local and transitory in nature, they often have a strong effect on sonar operations.

EXAMPLE OUTPUT

There are three graphic outputs available with the SSX product:

1. A shaded shallow sound channel axis depth display. The amount of shading indicates the range of depth in feet. See figure 9-10.

Clear	None (or depth <150 ft or >1000 ft)
Light	axis depth 150-300 feet
Medium	axis depth 300-600 feet
Heavy	axis depth 600 – 1,000 feet

2. A shaded shallow sound channel magnitude (strength) display. The amount of shading indicates the

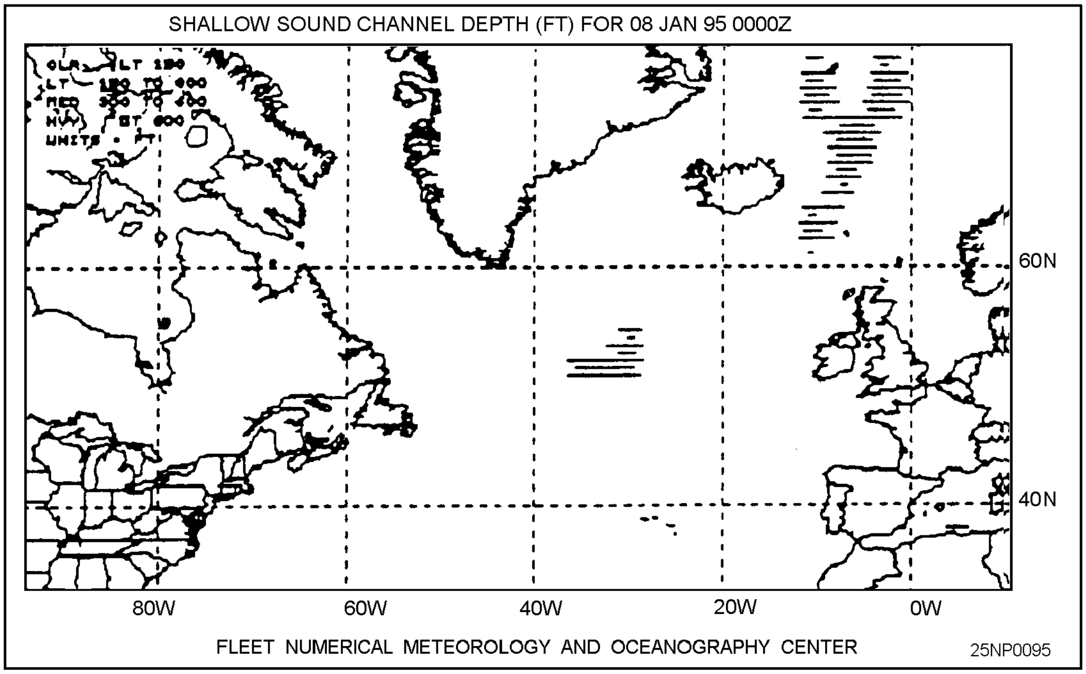

Figure 9-10.-A shaded shallow sound channel axis depth display.

strength of the shallow sound channel (SSC) at those grid points where these channels exist and meet minimal descriptive criteria. See figure 9-11.

Clear	No shallow sound channels or strength <3 ft/sec
Light	Strength 3 – 5 ft/sec
Heavy	Strength>-5 ft/sec

3. A shaded shallow sound channel cutoff frequency display. The amount of shading indicates the limiting frequency of the shallow sound channel. See figure 9-12.

Clear	No shallow channels or frequency> 300 Hertz
Light	Frequency 151 – 300 Hertz
Medium	Frequency 51-150 Hertz
Heavy	Frequency 1- 50 Hertz

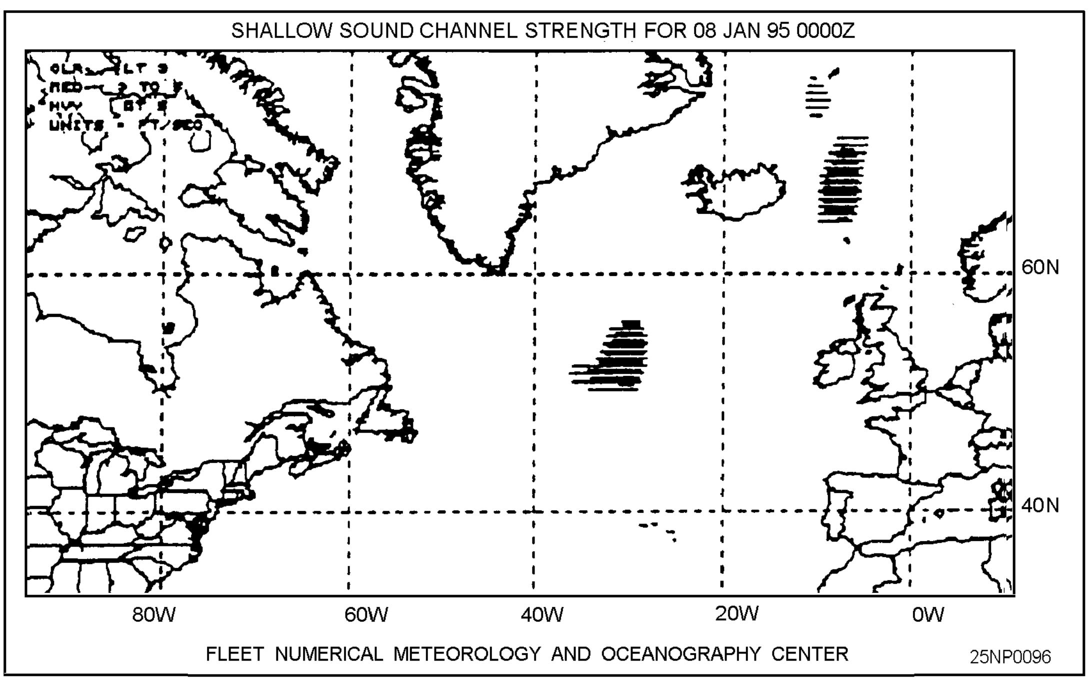

Figure 9-11.-A shaded shallow sound channel strength display.

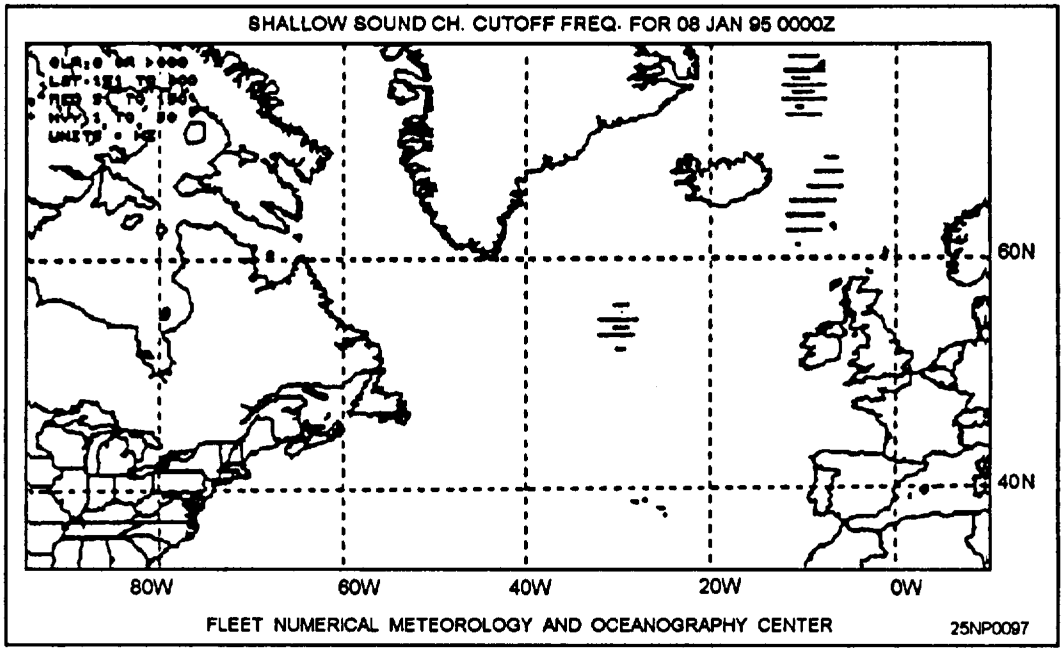

Figure 9-12.-A shaded shallow sound channel cutoff frequency display.

The first portion of this chapter was devoted to those oceanographic products that were accessed using the NODDS.

We will now discuss phenomena and principles covered in the *Fleet Oceanographic and Acoustic Reference Manual,* RP33. A brief overview will be presented for each area discussed. For more information, see RP33.

FORECASTING EFFECTS OF AMBIENT NOISE

LEARNING OBJECTIVES Distinguish ambient noise from self-noise. Identify characteristics of surface ship traffic and sea-state noises.

The problem of listening for recognizable sounds in the ocean is to distinguish them from the total noise background. Ambient noise is that part of the total noise background not due to some identifiable localized source. It exists in the medium independent of the observer's activity. Interfering noise sources that are located on, or are a part of, the platform on which a sensor is installed are sources of self-noise.

AMBIENT NOISE

Deep-sea ambient noise measurements have been made over a frequency range from 1 Hz to 100 kHz. Over this range the noise is due to a variety of sources, each of which may be dominant in one region of the spectrum. Principal sources of ambient noise in the frequency range of about 30 Hz to 10 kHz are distant shipping and wind-generated surface agitation. Other important contributors are rain, ice, and biological activity. Under certain conditions, these latter sources of background noise can seriously interfere with detection systems; however, not enough is known about their occurrence to permit meaningful predictions. Figure 9-13 indicates ambient levels of shipping and sea noise.

Figure 9-13 may be analyzed as follows:

- Along the Gulf Stream and major trans-Atlantic shipping lanes, the heavy traffic predictor (curve F) forecasts average noise within ±2 dB at 100 and 200 Hz. Maximum values usually occur with ships closer than 10 nmi and the values follow the individual ship's curve (curve G), Minimum values vary radically but appear to group around the average traffic curve (curves D and E).
- For 440 Hz, the predictor curves appear to be 2 or 3 dB too low.

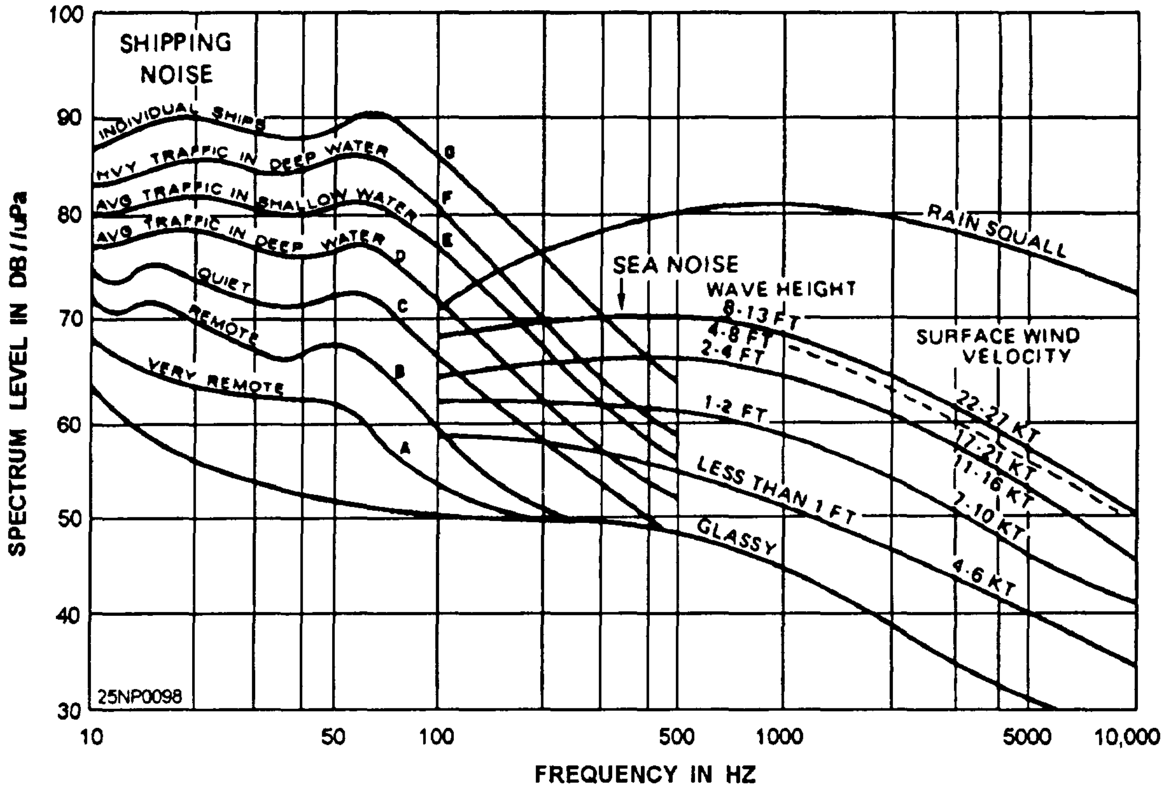

Figure 9-13.-Ambient noise levels.

- Four or more ships closer than 30 nmi constitute heavy noise, with ships closer than 10 nmi driving the noise level up to the individual ship's target curve (curve G). Where the bulk of the traffic is farther than 40 nmi, the average traffic curves (curves D and E) apply. This does not apply to a carrier task group.
- Correlations of noise intensity with distance to nearest ship, with all ships present in the shipping lanes, were negative. For areas not immediately in a heavy traffic area, ship concentration and distance became critical.

SURFACE-SHIP TRAFFIC NOISE

At the lower frequencies the dominant source of ambient noise is the cumulative effect of ships that are too far away to be heard individually. The spectrum of the noise radiated from ships as observed at great distances differs from the spectrum at close range due to the effect of frequency-dependent attenuation.

Sea-state noise

Sea state is a critical factor in both active and passive detection. Inactive sonobuoy detection, waves 6 feet or greater will start to produce a sea-state-limited situation. For shipboard sonar systems, location of the sonar dome, ship's speed, course, and relation to the sea all have an effect. The limiting situation is generally sea state 4 or 5. For passive detection, the noise level created by wind waves of 10 feet or greater will result in a minimum of antisubmarine warfare (ASW) operational effectiveness, depending on the type of sensor.

WIND-GENERATED NOISE.– Sea-state noise generated by surface wave activity is usually the primary component over a range of frequencies from 300 Hz to 5 kHz. It maybe considered to be one of the most critical variables in active and passive detection.

SEA-STATE NOISE LEVELS.– The wind-generated noise level decreases with increasing acoustic frequency and increases with increasing sea state (approximately 6 dB for each increase in sea state). It is very important to understand that all sound-sensor ranges are reduced by additional noise, and that there can be a 20-dB spread in background noise between various sea states.

Other Ambient-noise Sources

Ambient noise is also produced by intermittent and local effects such as earthquakes, biologics, precipitation, ice, and breakage of waves.

PRECIPITATION.– Rain and hail will increase ambient-noise levels at some frequencies (usually between 500 Hz and 15 kHz). Large storms can generate noise at frequencies as low as 100 Hz and can substantial y affect sonar conditions at a considerable distance from the storm center.

ICE.– Sea ice affects ambient-noise levels in polar regions. Provided that no mechanical or thermal pressure is being exerted upon the ice, the noise level generally is relatively low during the growth of ice. According to investigations carried out in the Bering Sea, the noise level should not exceed that for a sea state 2, even for winds over 35 knots. The exception to this rule is extremely noisy conditions due to entrapped air.

BIOLOGICS.– Biological noise may contribute significantly to ambient noise in many areas of the ocean. The effect of biological activity on overall noise levels is more pronounced in shallow coastal waters than in the open sea. It is more pronounced in the tropics and temperate zones than in colder waters. By far the most intense and widespread noises from animal sources in shallow water observed to this time are those produced by croakers and snapping shrimp. Fish, more than crustaceans (crabs, lobsters, shrimp), are the source of biological noise in most of the open ocean.

Marine Mammals

Mammal sounds include a much greater range of frequencies than do the sounds of either crustaceans or fish. They have been recorded as low as 19 Hz (whale sounds) and as high as 196 kHz (porpoise sounds).

EVALUATING THE IMPACT OF BIOLUMINESCENCE

LEARNING OBJECTIVES: Identify the primary sources of bioluminescence in the oceans. Recognize distinguishing features of sheet, spark-type, glowing ball, and exotic light display luminescence.

Plankton organisms are chiefly responsible for bioluminescence in the sea. The smallest forms are luminescent bacteria that usually feed on decaying matter or live in various marine animals. However, with a supply of the proper nutrients, luminescent bacteria can develop in great masses in the sea, causing a general bluish-green glow in the water. The glow is usually diffused and barely detectable, although exceptionally bright displays caused by luminous bacteria occasionally are observed in coastal regions near the outflow of large rivers. The light given off frequently outlines the current front where the river and ocean meet.

TYPES OF BIOLUMINESCENT DISPLAYS

Bioluminescent displays may be classified according to their appearance. They are sheet, spark-type, glowing ball, and exotic light.

Sheet Bioluminescence

Most bioluminescence in the oceans is of a sheet-type display and is produced by one-celled organisms. This type is most commonly observed in coastal waters. The color is usually green or blue and many displays appear white when the organisms are present in great numbers.

Spark-type Bioluminescence

Spark-type displays are created by a large number of crustaceans. Most of these displays occur in colder, disturbed waters and only rarely in tropical waters. The light emitted gives the ocean surface a "twinkling" appearance.

Glowing-ball-type Bioluminescence

Glowing ball or globe-type displays are seen most frequently in the warmer waters of the world. The ocean may seem to be full of balls or discs of light, some flashing brightly as they are disturbed, and others dimming after the initial disruption has ceased. The light given off is usually blue or green; displays of white, yellow, orange, or red have occasionally been reported.

Luminescent jellyfish also cause many glowing-ball displays. Large shining round or oval spots of light may appear in the water.

Exotic Light Displays

Exotic light formations like wheels, undulating waves of light, and bubbles of light appear to be separate and distinct from the displays previously discussed. The cause of such phenomena are still unknown.

ARABIAN SEA BIOLUMINESCENCE

The Arabian Sea is one of the richest areas in the world for marine bioluminescence. It is known to appear with the onset of the southwest and northeast monsoons.

Reports indicate that there is no correlation between this phenomena and meteorological conditions.

UNDERWATER VISIBILITY

LEARNING OBJECTIVES: Recognize the six factors affecting underwater visibility. Compare water transparency in various parts of the North Atlantic ocean.

Visibility in seawater is restricted in a manner somewhat similar to the restriction of visibility in the atmosphere. The restriction in seawater differs from that in the atmosphere primarily because of scattering (predominant in coastal waters) and absorption (predominant in deep, clear ocean waters).

FACTORS AFFECTING UNDERWATER VISIBILITY

Underwater visibility depends primarily upon the transparency of the water, reflectance and contrast, water color, sea state, incident illumination, and optical image.

Transparency

The term *transparency* is often thought of as that property of water that permits light of different wavelengths to be transmitted; transparency is sometimes measured as the percent of radiation penetrating a path length of 1 meter. However, the most commonly used definition and measurement of transparency, as applied to underwater visibility, is the average depth below sea surface at which a Secchi disc (white disc) first disappears and then reappears at the surface to an observer who successively lowers and raises the disc.

The degree to which seawater becomes transparent is a function of the combined effects of scattering and absorption of light by the water surface, suspended, organic and inorganic particulate matter, dissolved substances, plankton, and the water's molecular structure.

Reflectance and Contrast

For a target to be visible, it must contrast with its background.

Water Color

Deep (clear) water is very transparent to the blue portion of the light spectrum and less transparent to the green, yellow, red, and violet portions. In the more turbid coastal waters, green and yellow light penetrates to greater depths than does blue.

Sea State

Irregular sea surfaces affect visibility in several ways. Variable refraction results in a reduction of the contrast of a target. Winds that barely ruffle the surface reduce contrast of a target by as much as 40 percent.

Incident Illumination

The amount of incident illumination, as determined by cloud coverage and the sun above the horizon, is a definite consideration in underwater visibility.

Optical Image

The optical image of a target can be due to its own light, to reflected light, or to its being silhouetted against an illuminated background.

GEOGRAPHIC VARIATION OF TRANSPARENCY

Figure 9-14 depicts the Seawater transparency of the North Atlantic. Figure 9-14 also shows that deep North Atlantic waters range in transparency from approximate y 50 feet off the continental slope to over 115 feet in the Sargasso Sea.

EFFECTS OF OCEAN FRONTS, EDDIES, AND UPWELLING

LEARNING OBJECTIVES Define oceanic fronts, eddies, and upwelling. Recognize typical locations of oceanic fronts, eddies, and upwelling in the Pacific and Atlantic oceans. Be familiar with the effects of oceanic fronts, eddies, and upwelling on acoustics. Recognize oceanic front, eddy, and upwelling locations using satellite data.

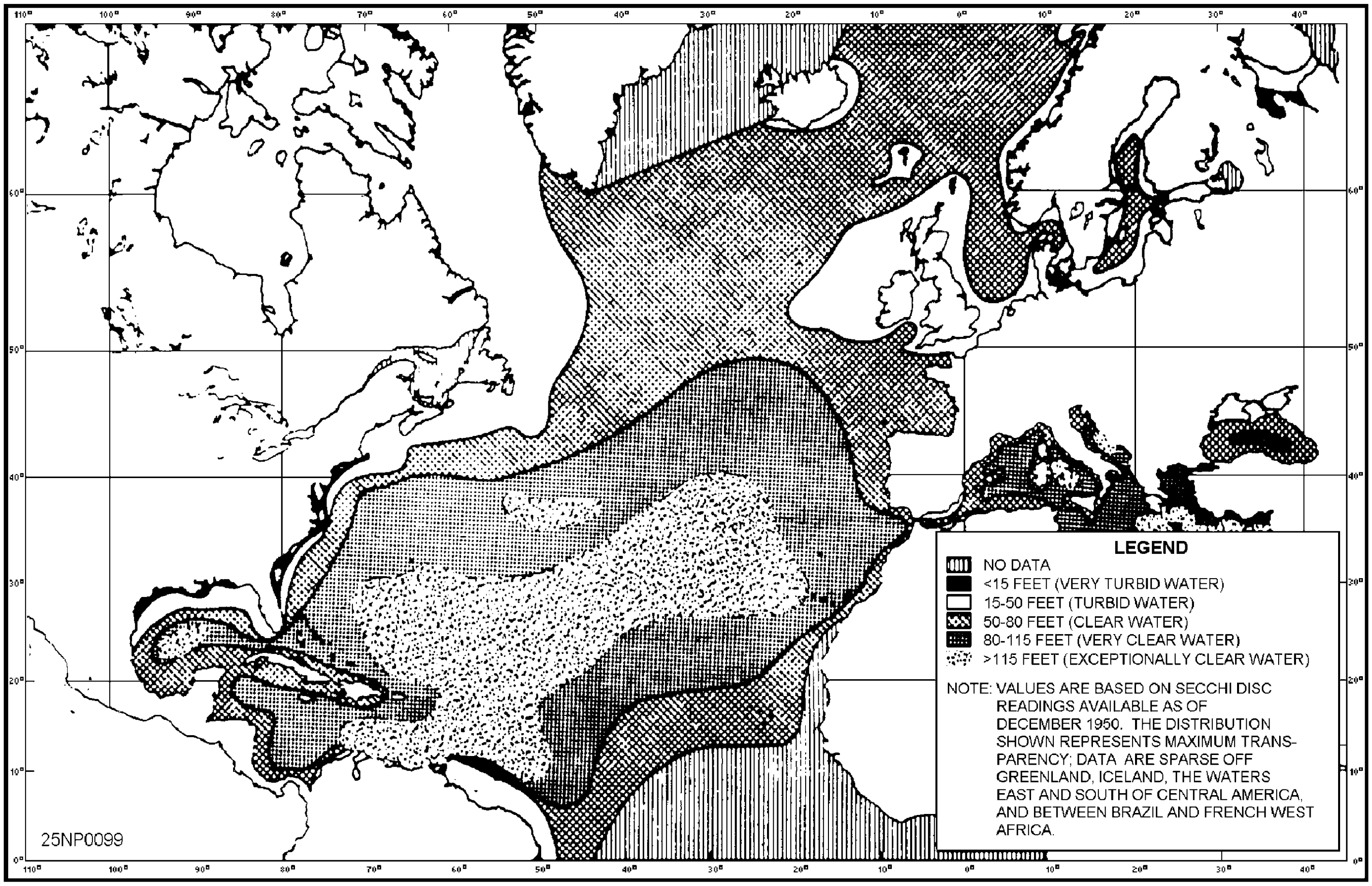

Figure 9-14.-Seawater transparency of the North Atlantic.

First of all, let's consider the definitions of fronts, eddies, and upwelling.

OCEAN FRONTS

An ocean front is the interface between two water masses of different physical characteristics. Usually, fronts show strong horizontal gradients of temperature and salinity, with resulting density variation and current shear. Some fronts which have weak horizontal gradients at the surface have strong gradients below the surface. In some cases, gradients are weak at all levels, but variability across the front, as reflected by the shape of the thermal profile, is sufficient to complicate sound transmission.

A useful definition for the purpose of naval operations can be stated as: A tactically significant front is any discontinuity in the ocean which significantly alters the pattern of sound transmission and propagation loss. Thus, a rapid change in the depth of the sound channel, a difference in the sonic-layer depth, or a temperature inversion would denote the presence of a front.

OCEAN EDDIES

An eddy is a rotating parcel of fluid. As such, the eddy concept can be applied to phenomena ranging from momentary vortices in the sea-surface flow to the steady circulation of a basin-wide gyre. For ASW application, however, mesoscale features of 100 to 400 km (55 -215 nmi) are most important. These eddies are rotating masses of water that have broken off from a strong front such as the Gulf Stream. They can be considered circular fronts with water trapped inside having different physical properties from the surrounding water.

UPWELLING

Surface winds cause vertical water movements. Upwelling can be caused by winds blowing across the ocean surface. Coastal upwelling occurs where prevailing winds blow parallel to the coast. Winds cause surface water to move, but the presence of land or a shallow bottom restricts water movements. When the wind-induced water movement is off-shore, subsurface water flows to the surface near the coast. This slow, upward flow, from 100 to 200 meters (300 to 600 feet) deep, replaces surface waters blown seaward. Coastal upwelling is common along the west coast of continents.

Upwelling also occurs in the equatorial open oceans. This wind-induced upwelling is caused by the change indirection of the Coriolis effect at the equator. Westward flowing, wind-driven surface currents near the equator flow northward on the north side and southward on the south side of the equator.

TYPICAL LOCATIONS OF PACIFIC AND ATLANTIC OCEAN FRONTS

Figures 9-15 and 9-16 show approximate locations of Pacific and Atlantic Ocean fronts. The dashed lines are *weak* fronts, which may not be significant to ASW operations. The *solid* lines represent the moderate fronts which, under certain conditions, may be important operationaly. The *heavy* lines are the strong fronts, which usually have a significant effect on ASW tactics.

Although it is not possible to show typical locations of large ocean eddies due to their constant motion, they are generally found on either side of strong fronts such as the Gulf Stream or the Kuroshio. Smaller eddies, such as those formed by upwelling can be found in any part of the ocean.

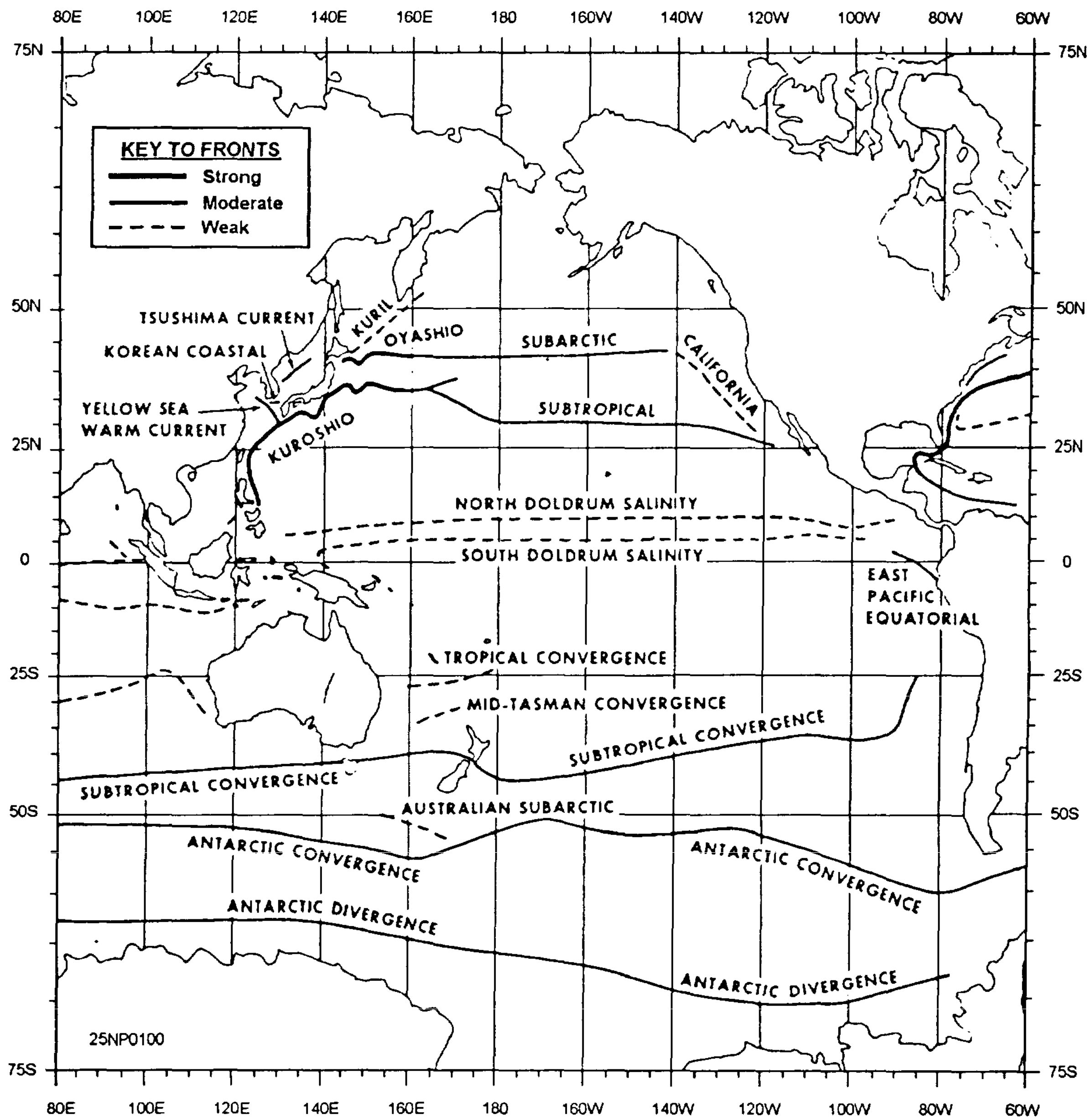

Figure 9-15.-Mean position of Pacific fronts.

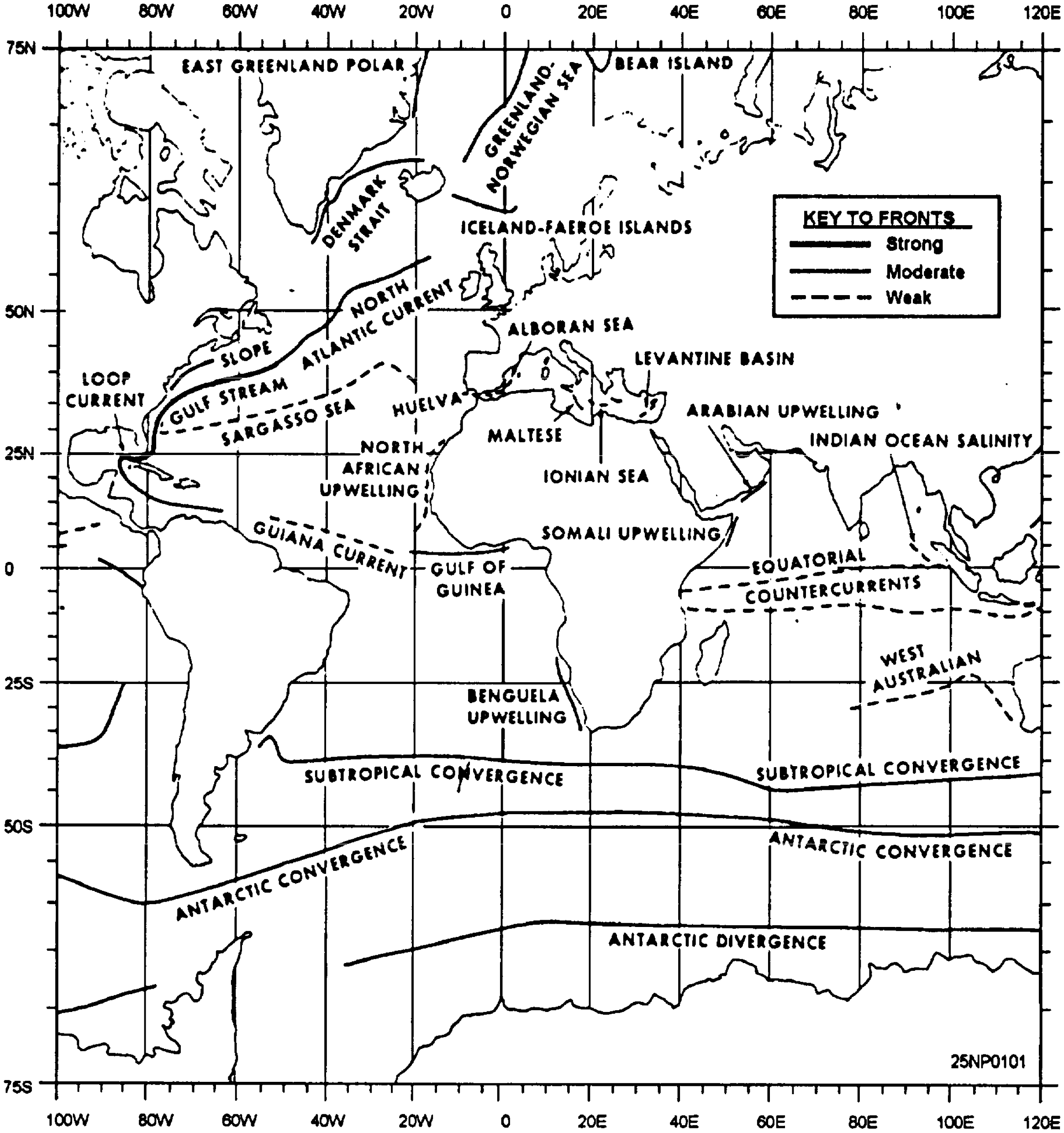

Figure 9-16.-Mean position of Atlantic fronts.

ACOUSTIC EFFECTS OF FRONTS

The following changes can be of significant importance to acoustics as a front is crossed:

- Near-surface sound speed can change by as much as 100 ft/sec. Although this is due to the combined effect of changing temperature and salinity, temperature is usually the dominant factor.
- Sonic-layer depth (SLD) can change by as much as 1,000 feet from one side of a front to the other during certain seasons.
- A change of in-layer and below-layer gradient usually accompanies a change in surface sound speed and SLD.
- Depth of the deep sound-channel (DSC) axis can change by as much as 2,500 feet when crossing from one water mass to the other.
- Increased biological activity generally found along a front will increase reverberation and ambient noise.
- Sea-air interaction along a frontal zone can cause a dramatic change in sea state and thus increase ambient levels.

- Changes in the vertical arrival angle of sound rays as they pass through a front can cause towed array bearing errors.

It is clear that any one of these effects can have a significant impact on ASW operations. Together they determine the mode and range of sound propagation and thus control the effectiveness of both short- and long-range acoustic systems. The combined effect of these characteristics is so complex that it is not always possible to develop simple rules for using ocean fronts for ASW tactics. For example, the warm core of the Gulf Stream south of Newfoundland will bend sound rays downward into the deep sound channel, thereby enhancing the receiving capability of a deep receiver. The same situation with a slightly shallower bottom south of Maine may create a bottom-limited situation, and the receiving capability at the same hydrophore will be impeded. In view of this, the acoustic effects of a front must be determined for each particular situation by using multiprofile (range-dependent environment) acoustic models. The input for these models can come from detailed oceanographic measurements, or from historical data in combination with surface frontal positions obtained from satellites.

DETERMINING FRONTAL POSITION USING SATELLITE DATA

Most fronts exhibit surface-temperature signatures that can be detected by satellite infrared (IR) sensors and are used in determining frontal positions. Figure 9-17 is an example of a satellite IR image obtained by the TIROS-N showing the location of the Gulf Stream and formation of a warm ring. Because surface-temperature gradients are not always reliable indicators of the subsurface front, satellite images must be interpreted by a skilled analyst, preferably in combination with data from other sources such as BTs. Automatic interpretation of satellite data is also being developed using techniques generally known as automatic imagery-pattern recognition or artificial intelligence.

Now let's discuss oceanographic effects on mine warfare (MIW). *Environmental Effects on Weapons Systems and Naval Warfare (U),* (S)RP1, provides further detail on this subject.

MINE WARFARE (MIW)

LEARNING OBJECTIVES Recognize the parameters affecting MIW operations. Identify the various mine hunting sonars. Be familiar with the procedures for obtaining MIW support products.

MIW is the strategic and tactical use of sea mines and their countermeasures. MIW may be offensive (mining to interfere with enemy ship movement) or defensive (mining to defend friendly waters [mine-countermeasures]) in nature. Mine warfare is almost always conducted in nearshore areas that present special environmental conditions not usually encountered in open ocean areas, including:

- Sound speed that is highly dependent upon salinity. Although salinity may be treated as constant for open ocean areas, fresh water runoff creates strong salinity gradients in nearshore areas.
- Ambient noise that is higher than normal.
- Biologic activity levels and diversity that are higher.
- Nearshore areas that typically have a high level of nonmilitary activity.
- Land runoff that generates much more turbidity than for open ocean areas.

MINE WARFARE ENVIRONMENTAL SUPPORT

MIW planning (mining and mine countermeasures) requires a considerable environmental input. The following parameters should be considered for discussion in any MIW environmental support package:

- Water depth
- Physical properties of water column
- Tides
- Currents
- Sea ice
- Bottom characteristics

Figure 9-17.-An example of a satellite IR image obtained by the TIROS-N.

- Biologic activity
- Wave activity

PRINCIPAL MINE HUNTING SONAR SYSTEMS

All mine hunting sonars operate at very high frequencies to achieve high resolution

- AN/SQQ-14: ACME and AGGRESSIVE class MSOs
- AN/SQQ-32: Newest mine hunting sonar; installed on AVENGER class MCMs and planned for LERICI class MHCs
- AN/ALQ-14: RH-53-53D/E MCM helicopters

ENVIRONMENTAL SUPPORT SYSTEMS AND PRODUCTS FOR MINE WARFARE

The following support systems and products are available in TESS 3/MOSS:

- Oceanography and acoustic support modules
- Solar and lunar data (rise and set times, percent illumination)
- Tidal data

Other useful publications/products include:

- MIW pilots
- NAVOCEANO Environmental Guides
- NAVOCEANO drift trajectory support product
- Mk 60 CAPTOR Mine Environmental Guides
- Sailing Directions and Planning Guides

SUMMARY

In this chapter we first discussed oceanographic products available using the Navy Oceanographic Data Distribution System (NODDS). General descriptions and example outputs were covered for each. Effects of ambient noise, bioluminescence, underwater visibility, ocean fronts, eddies, and upwelling were then presented along with definitions and general descriptions of each, Lastly, MIW issues of interest to the Aerographer were discussed along with an overview of environmental support, Also presented was a listing of mine hunting sonars and available support products.